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(54) RADIO APPARATUS AND METHOD HAVING A D.C. COMPONENT SIGNAL SUPERPOSED ON A TRANSMISSION SIGNAL

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(57) ABSTRACT

In a radio apparatus including a transmitter unit and an antenna unit, a detector is located in the vicinity of an antenna in the antenna unit rather than in the transmitter unit. The detector supplies a rectified signal from a transmission wave which is to be radiated from the antenna and the rectified signal is supplied to a control circuit in the transmission unit as a feedback component. A control signal is then determined by the control circuit based on the rectified signal and supplied to a variable attenuator to increase/decrease power of the transmission wave.

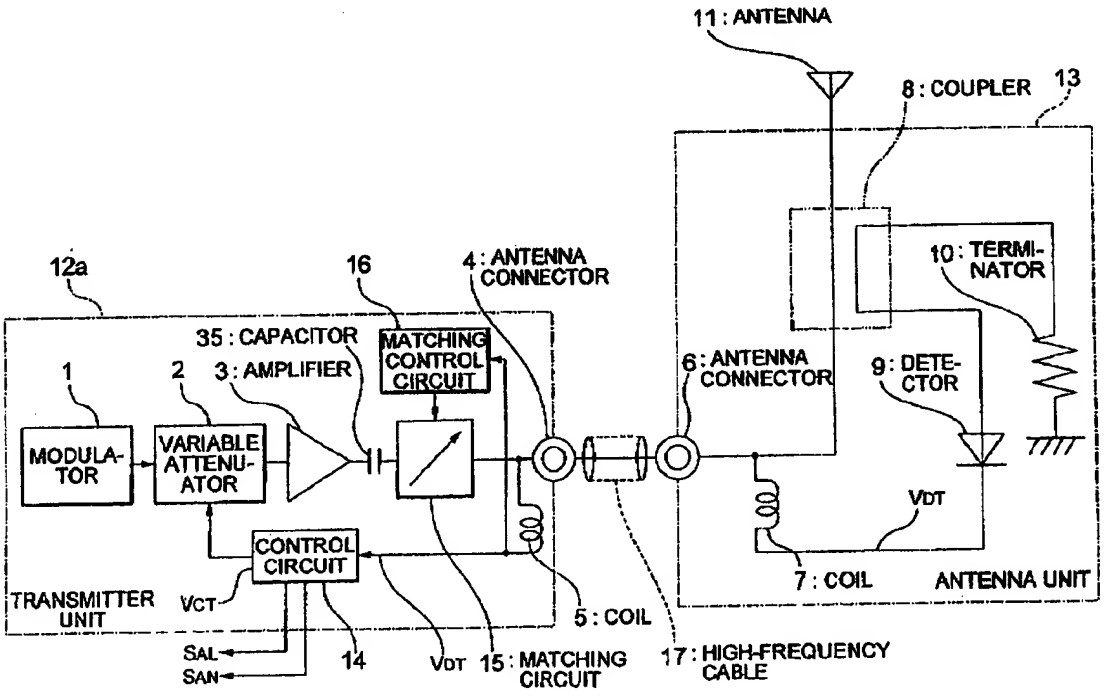


FIG. 1

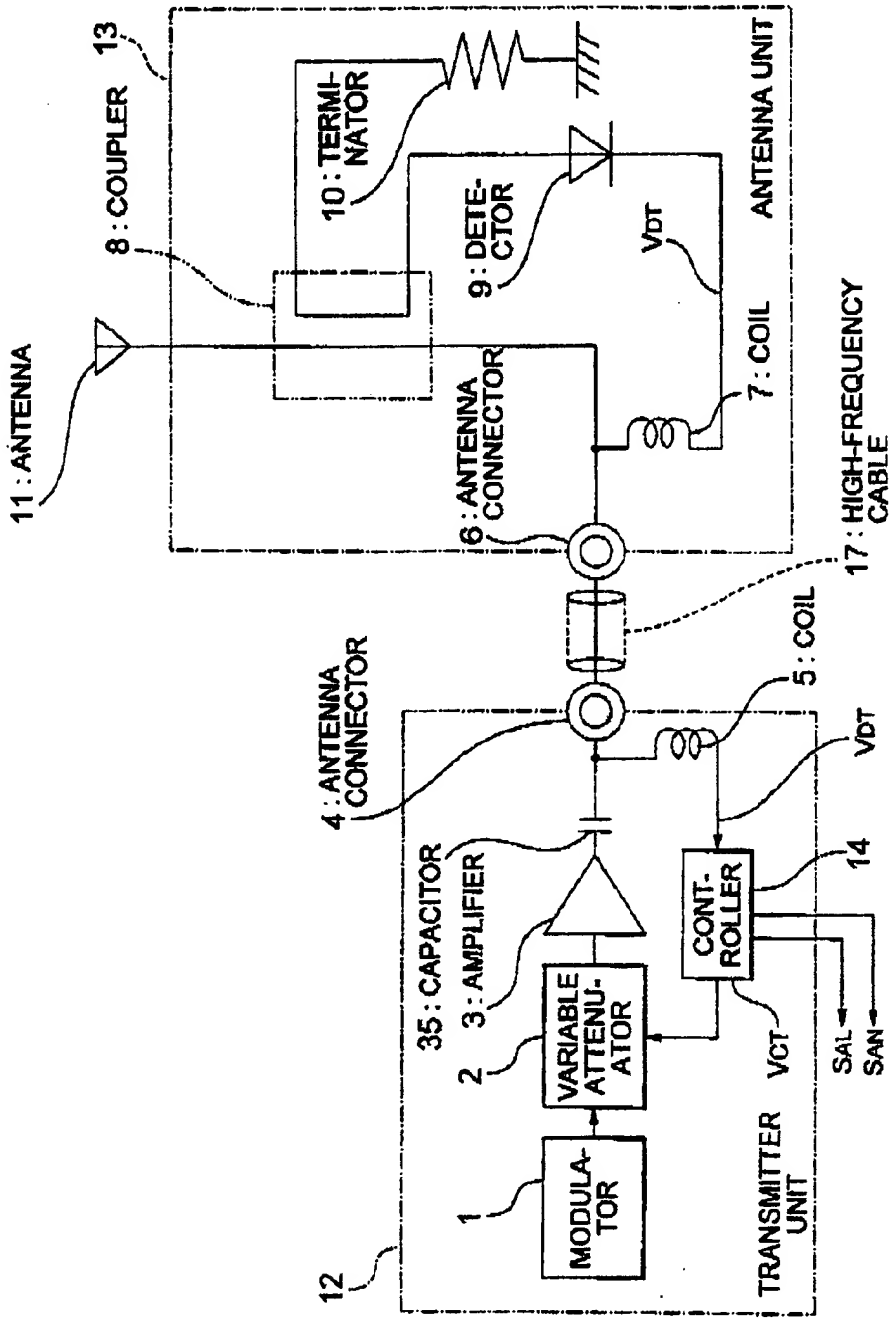

13
8 : COUPLER
10 : TERMI-NATOR
9 : DETE-CTOR
VDT
ANTENNA UNIT
11 : ANTENNA
6 : ANTENNA CONNECTOR
7 : COIL
17 : HIGH-FREQUENCY CABLE
4 : ANTENNA CONNECTOR
5 : COIL
VDT
35 : CAPACITOR
3 : AMPLIFIER
CONT-ROLLER
14
2
VARIABLE ATTENU-ATOR
VCT
SAL
SAN
1
MODULA-TOR
TRANSMITTER UNIT
12

FIG. 2

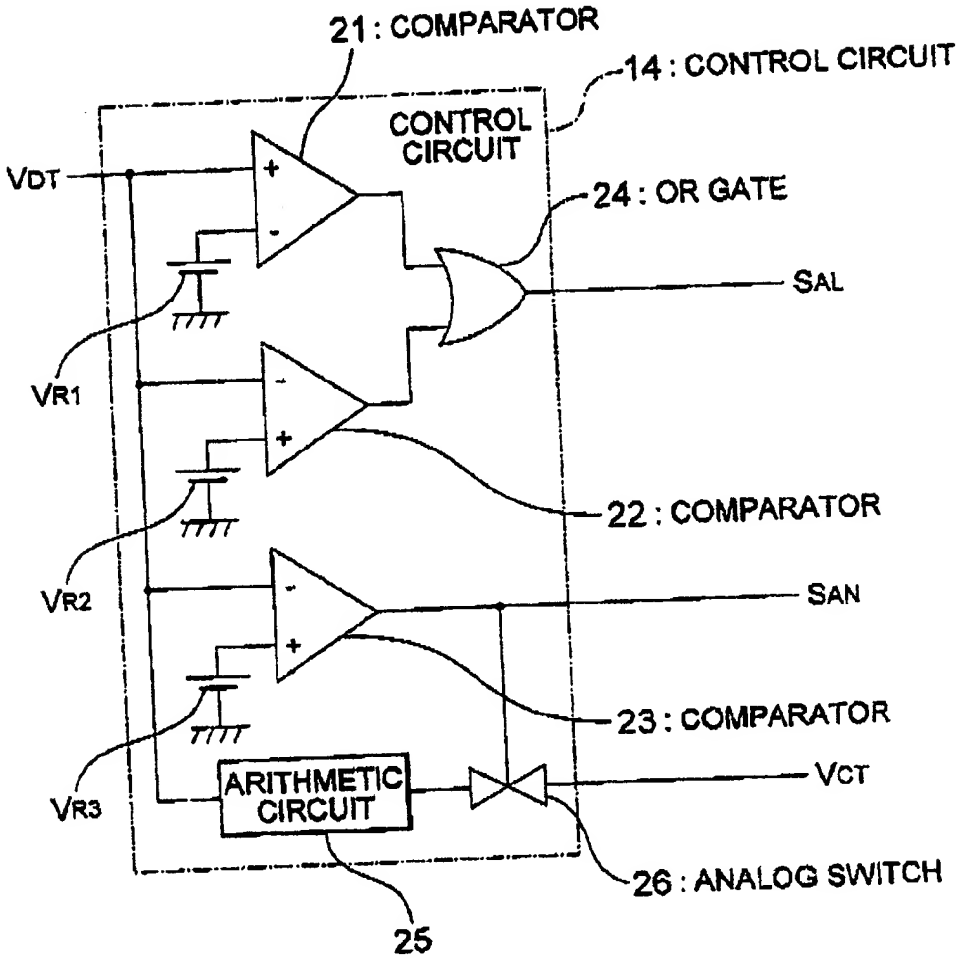
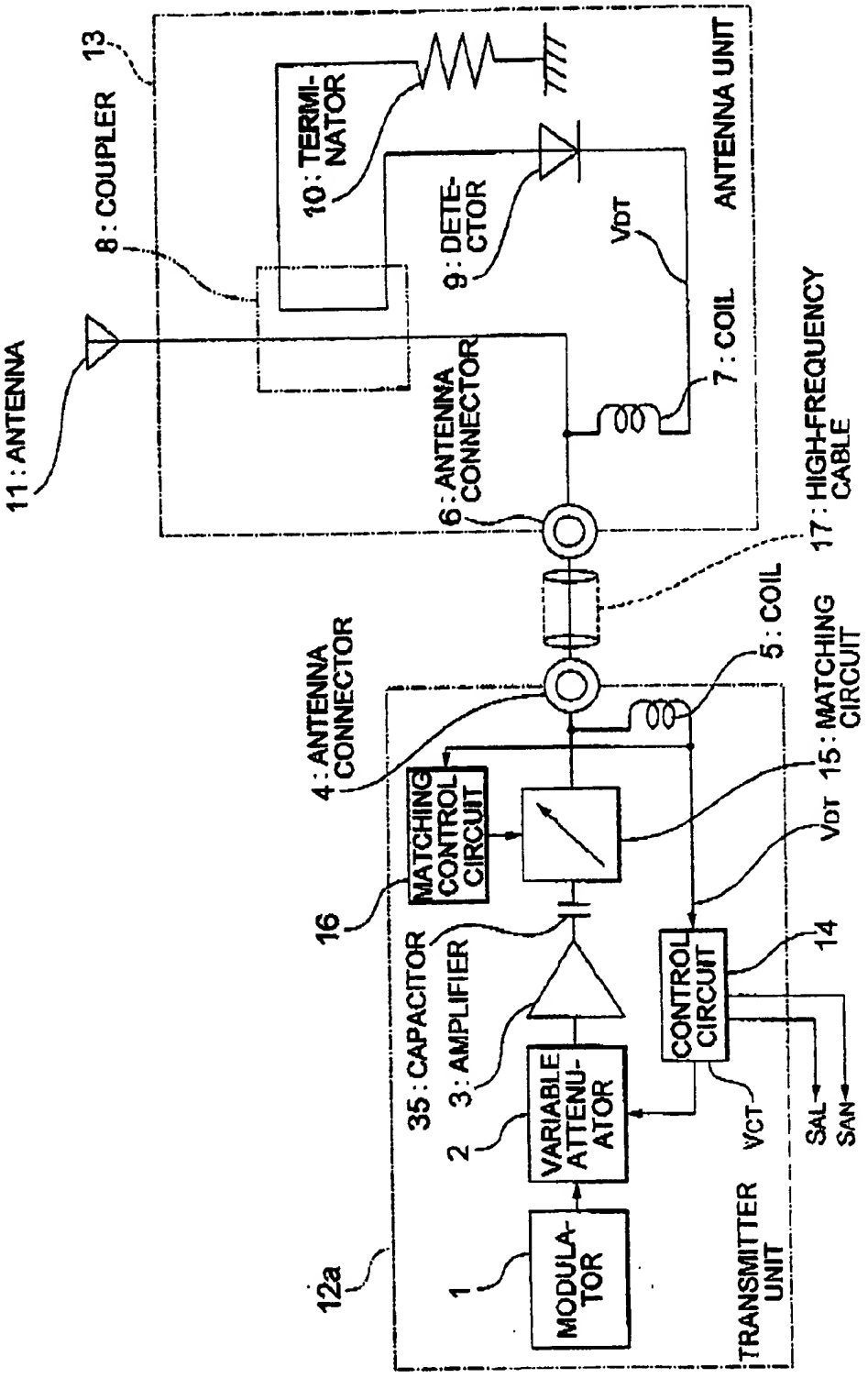

21 : COMPARATOR
14 : CONTROL CIRCUIT
CONTROL CIRCUIT
VDT
24 : OR GATE
SAL
VR1
22 : COMPARATOR
VR2
SAN
23 : COMPARATOR
VR3
ARITHMETIC CIRCUIT
VCT
26 : ANALOG SWITCH
25

FIG. 3


13
8: COUPLER
10: TERMI-NATOR
9: DETE-CTOR
VDT
ANTENNA UNIT
11: ANTENNA
6: ANTENNA CONNECTOR
7: COIL
17: HIGH-FREQUENCY CABLE
4: ANTENNA CONNECTOR
5: COIL
15: MATCHING CIRCUIT
MATCHING CONTROL CIRCUIT
16
VDT
35: CAPACITOR
3: AMPLIFIER
CONTROL CIRCUIT
14
2
VARIABLE ATTENU-ATOR
VCT
SAL
SAN
12a
1
MODULA-TOR
TRANSMITTER UNIT

RADIO APPARATUS AND METHOD HAVING A D.C. COMPONENT SIGNAL SUPERPOSED ON A TRANSMISSION SIGNAL

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] This invention relates to a radio apparatus which is used in a base station in a mobile telephone system and which has receiving/sending equipment and an antenna, in particular, to a method of controlling the radio apparatus in which the receiving/sending equipment and an antenna are disposed apart from each other.

[0003] 2. Description of the Related Art

[0004] In general, a mobile telephone system has a plurality of base stations and a great number of mobile stations communicable with the base station or stations. In this event, each of the base stations is structured by a transmitter/receiver and an antenna unit which is remote from the transmitter/receiver by several meters or so and which is connected to the transmitter/receiver through a cable, such as a coaxial cable. The transmitter/receiver is located indoors while the antenna unit is placed outdoors.

[0005] Under the circumstances, it is necessary to detect, on a side of the transmitter/receiver, failure or trouble which might occur in the antenna unit. To this end, a failure detection circuit is usually included in the transmitter/receiver of each base station to detect the failure or the trouble in the antenna unit and to produce an alarm on detection of such failure or trouble.

[0006] However, it has been found out that such a failure detection circuit can not correctly detect the failure or trouble in the antenna unit. This is because the antenna unit is distant from the transmitter/receiver, which causes a standing wave to occur on the cable between the antenna unit and the transmitter/receiver.

[0007] Specifically, occurrence of the standing wave might often result in wrong detection of the failure or trouble in the antenna unit, since the standing wave has, at a demodulating point, a node at which the standing wave becomes the smallest in amplitude.

SUMMARY OF THE INVENTION

[0008] Therefore, it is an object of the invention to solve the above problem.

[0009] It is also another object of the invention to provide a radio apparatus and method of controlling the radio apparatus which can accurately detect trouble of the antenna apparatus which is disposed apart from the receiving/sending apparatus and troubles of connecting between thereof, efficiently send a signal, and protect the sending apparatus when the troubles occur.

[0010] According to a first aspect of the invention, there is provide a radio apparatus including an antenna unit which radiates a transmission signal and a transmitter unit which supplies the transmission signal to the antenna unit through a line between the transmitter unit and the antenna unit. Here, the antenna unit comprises a coupler which partially extracts the transmission signal to produce an extracted signal and a rectifying circuit which rectifies the extracted signal into a d.c. component signal and superposes the d.c component signal on the transmission signal. On the other hand, the transmission unit comprises a separating circuit which separates the d.c. component signal from the transmission signal.

[0011] According to a second aspect of the invention, the rectifying circuit includes a detector which rectifies the extracted signal into the d.c. component signal.

[0012] According to a third aspect of the invention, the rectifying circuit includes a first coil which superposes the d.c. component signal on the transmission signal.

[0013] According to a fourth aspect of the invention, the separating circuit includes a second coil which separates the d.c. component signal from the transmission signal.

[0014] According to a fifth aspect of the invention, the transmitter unit includes a control circuit which compares the d.c. component signal separated from the transmission signal with a predetermined reference signal and detects trouble when the d.c. component signal is lower than the predetermined reference signal.

[0015] According to a sixth aspect of the invention, the control circuit further decreases the power of the transmission signal when the d.c. component signal is lower than the predetermined reference signal.

[0016] According to a seventh aspect of the invention, the transmitter unit further comprises a variable attenuator which varies the power of the transmission signal and an arithmetic circuit which controls the variable attenuator based on a voltage level of the d.c. component signal separated from the transmission signal.

[0017] According to an eighth aspect of the invention, the transmitter unit further comprises a matching circuit which matches an impedance of the transmitter unit to that of the antenna unit and a matching control circuit which controls the matching circuit based on a voltage level of the d.c. component signal separated from the transmission signal.

[0018] According to a ninth aspect of the invention, the transmitter unit includes a control circuit which determines whether or not the d.c. component signal which is separated from the transmission signal falls within a predetermined range and detects trouble when the d.c. component signal does not fall within the predetermined range.

[0019] According to a tenth aspect of the invention, there is provided a method of controlling a radio apparatus including an antenna unit which radiates a transmission signal and a transmitter unit which supplies the transmission signal. Here, the antenna unit and the transmitter unit being connected electrically from each other, and the method comprises the steps of partially extracting, at the antenna unit, the transmission signal, rectifying, at the antenna unit, the extracted signal into a d.c. component signal, superposing, at the antenna unit, the d.c. component signal on the transmission signal, and separating, at the transmitter unit, the d.c. component signal from the transmission signal.

[0020] According to an eleventh of the invention, there is provided a method of controlling an antenna unit remote from a transmitter unit. Here, the antenna unit which radiates the transmission signal and the transmitter unit which supplies the transmission signal are included in a radio appa-

ratus and connected electrically from each other, and the method comprises the steps of partially extracting the transmission signal, rectifying the extracted signal into a d.c. component signal, and superposing the d.c. component signal on the transmission signal.

[0021] According to a twelfth of the invention, there is provided a method of controlling a transmitter unit. Here, the transmitter unit which supplies a transmission signal and an antenna unit which radiates the transmission signal are included in a radio apparatus and connected electrically from each other, and the method comprises the step of receiving a d.c. component signal via the transmission signal from the antenna unit and separating the d.c. component signal from the transmission signal.

[0022] According to a thirteenth of the invention, the method further comprises the steps of comparing the d.c. component signal which is separated from the transmission signal with a predetermined reference signal and detecting trouble when the d.c component signal is lower than the predetermined reference signal.

[0023] According to a fourteenth of the invention, the method further comprises the step of decreasing the power of the transmission signal when the d.c. component signal is lower than the predetermined reference signal.

[0024] According to a fifteenth of the invention, the method further comprises the steps of varying the power of the transmission signal based on a voltage level of the d.c. component signal separated from the transmission signal and controlling intensity of the transmission signal which is radiated from the antenna unit so that the intensity may be equal to a predetermined value.

[0025] According to a sixteenth of the invention, the method further comprises the step of controlling matching of an impedance of the transmitter unit to that of the antenna unit so that a voltage level of the d.c. component signal separated from the transmission signal may become maximum.

[0026] According to a seventeenth of the invention, the method further comprises the step of determining whether or not the d.c. Component signal which is separated from the transmission signal falls within a predetermined range and detecting trouble when the d.c. component signal does not fall within the predetermined range.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] **FIG. 1** shows a block diagram of a radio apparats according to a first embodiment of the invention;

[0028] **FIG. 2** shows a block diagram of an example of a control circuit **14** of the first embodiment shown in **FIG. 1**; and

[0029] **FIG. 3** shows a block diagram of a radio apparatus according to a second embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0030] [First Embodiment of the Invention]

[0031] Hereinafter, descriptions will be made about a first embodiment of the invention with reference to accompanying drawings.

[0032] As shown in **FIG. 1**, a radio apparatus according to the first embodiment of the invention includes a transmitter unit **12** which may be incorporated in a transmitter/receiver (not shown) disposed indoors and an antenna unit **13** which is close to an antenna **11** and which is disposed outdoors.

[0033] Also, the transmitter unit **12** and the antenna unit **13** are connected to each other through a high-frequency cable **17**, such as a coaxial cable.

[0034] In **FIG. 1**, the transmitter unit **12** includes a modulator **1** which produces a modulated wave, a variable attenuator **2** which has a variable attenuation factor controlled by a control circuit **14** as described later, and an amplifier **3**.

[0035] The modulated wave which is modulated by the modulator **1** is supplied to the amplifier **3** through the variable attenuator **2**.

[0036] The modulated wave is amplified by the amplifier **3** into an amplified signal of predetermined electric power, and is supplied from an antenna connector **4** through a capacitor **35**. The capacitor **35** serves to cut a d.c. component.

[0037] The antenna connector **4** is connected to one end of a coil **5**, and the other end of the coil **5** is connected to the control circuit **14**.

[0038] The coil **5** has an inductance specified by a high reactance value at a frequency of the modulated wave (for example 1.9 GHz) and, consequently, allows only a d.c. component to pass therethrough.

[0039] The control circuit **14** supplies a control voltage V_{ct} having a value based on the d.c. component which passes through the coil **5** and controls the attenuation factor of the above-described variable attenuator **2** and produces an ALC alarm signal S_{AL} when any failure is detected by the control circuit **14**.

[0040] An antenna connector **6** is attached to the antenna unit **13** and is connected to the antenna **11** through a coupler **8** including a directional coupler.

[0041] One end of the coupler **8** is terminated through a terminator **10**, such as resistor, while the other end of the coupler **8** is connected to a detector **9**.

[0042] The illustrated detector **9** is formed by a diode for rectification. The diode may be replaced by a smoothing circuit including a capacitor.

[0043] In the illustrated example, the detector **9** has an anode electrode connected to the coupler **8** and a cathode electrode connected to the antenna connector **6** rough a coil **7**.

[0044] The coil **7** also has an inductance specified by a high reactance value at a frequency of a transmission wave sent through the antenna **11**.

[0045] The transmission wave is obtained by being modulated by the modulator **1** of the transmitter unit **12** to be attenuated at the variable attenuator **2** to a predetermined level which is determined under control of the control circuit **14** and to be amplified by the amplifier **3**.

[0046] The amplifier **3** amplifies the modulated wave into the amplified signal to supply the amplified signal to the antenna connector **4** as the transmission signal.

[0047] Then, the transmission wave is supplied from the antenna connector **6** to the antenna unit **13**, and radiated from the antenna **11** through the coupler **8**.

[0048] The transmission wave which is supplied from the antenna connector **6** to the antenna unit **13** is partially separated through the coupler **8**. The detector **9** rectifies the output of the coupler **8** to generate a rectified voltage V_{DT}. The rectified voltage V_{DT} is then superposed to the original transmission wave through the coil **7**.

[0049] On the other hand, the rectified voltage V_{DT} is partially sent back to the transmitter unit **12** and is taken out by the coil **5** to be supplied to the control circuit **14**. The control circuit **14** executes an ALC (Automatic Level Control) operation to control the attenuation factor of the variable attenuator **2** based on the rectified voltage V_{DT}.

[0050] In **FIG. 2**, the control circuit **14** includes comparators **21**, **22**, and **23**.

[0051] The comparators **21** and **22** are given reference voltages V_{R1} (in this embodiment, 4[V]) and V_{R2} (in this embodiment, 1[V]), respectively. Comparison results of the comparators **21** and **22** are supplied as ALC alarm signals S_{AL} through an OR gate **24**.

[0052] On the other hand, the comparator **23** is given a reference voltage V_{R3} (in this embodiment, 0.5[V]). Comparison result of the comparator **23** is produced as antenna alarm signal S_{AN}.

[0053] The control circuit **25** further includes an arithmetic circuit which is operable in response to the control voltage V_{CT} based on the rectified voltage V_{DT}. A detailed description and a figure about the arithmetic circuit **25** will be omitted because the arithmetic circuit **25** itself is known in the art.

[0054] The control voltage V_{CT} supplied from the arithmetic circuit is provided through an analog switch **26**, wherein the signal S_{AN} from the comparator **23** is given to a control input terminal of the analog switch **26**.

[0055] In this embodiment, the variable attenuator **2** is adjusted or trimmed so that a standard output may be supplied, and the rectified voltage V_{DT} at that time is set as the reference value (in this example, 3.0[V]).

[0056] The control circuit **14** increases the attenuation factor to decrease power of the transmission wave when the rectified voltage V_{DT} is higher than the predetermined reference value (for example, V_{DT}=3.5[V]). On the other hand, the control circuit **14** decreases the attenuation factor to increase power of the transmission wave when the rectified voltage V_{DT} is lower than the predetermined reference value (for example, V_{DT}=2.5[V]).

[0057] The control circuit **14** converges the rectified voltage V_{DT} (for example, 3[V]) by the above mentioned operations.

[0058] Also, the control circuit **14** supplies the ALC alarm signal S_{AL} when the rectified voltage V_{DT} does not fall within the predetermined voltage range. Therefore, in this embodiment, the ALC alarm signal S_{AL} is supplied when the rectified voltage V_{DT} exceeds 4 [V] or is lower than 1 [V].

[0059] In this embodiment, when any trouble occurs in electrical connection between the antenna connector **4** and the antenna connector **6** (for example, breakage of a wire), the transmission wave is not transmitted to the antenna unit **13**. Thereby, the detector **9** cannot produce the rectified voltage V_{DT} and, as a result, the rectified voltage V_{DT} is not sent back to the transmitter unit **12**.

[0060] Therefore, the voltage supplied to the control circuit **14** is close to 0. However, when the ALC operations are continued in the above case, the amplifier **3** generates maximum output since the control circuit **14** minimizes the attenuation factor of the variable attenuator **2**.

[0061] In order to avoid the above-mentioned situation, the control circuit **14** not only cuts off the control voltage V_{CT} to decrease output power of the amplifier **3** but also produces the antenna alarm signal S_{AN} when voltage supplied to the control circuit **14** is low (in this embodiment, less than or equal to 0.5 [V]).

[0062] [Second Embodiment of the Invention]

[0063] Hereinafter, a description is made about a second embodiment of the invention with reference to **FIG. 3**. Also, parts shown in **FIG. 3** each of which is the same as the corresponding part shown in **FIG. 1** have the same numeric symbols as the corresponding parts shown in **FIG. 1**, and description will be omitted about the same parts.

[0064] In **FIG. 3**, a transmitter unit **12***a* includes a matching circuit **15**, which is formed, for example, by a coil for resonance or variable capacitor for controlling voltage.

[0065] In the illustrated transmitter unit **12***a*, the transmission wave supplied from an amplifier **3** is provided to the antenna connector **4** through a capacitor **35** and the matching circuit **15**.

[0066] In this embodiment, a matching control circuit **16** controls the matching circuit **15** and determines a matching point by retrieving a point which has maximum rectified voltage V_{DT}.

[0067] The matching point is then stored in the matching control circuit **16** and is held until the antenna **11** is modified.

[0068] A description about operations after the determining operation, namely ALC operation will be omitted since the operations are the same as those of the first embodiment of the invention.

[0069] According to the invention, transmission output can be kept at a certain level, regardless of the distance between a transmitter unit and an antenna since the detector is located in the vicinity to the antenna rather than inside the transmitter unit.

[0070] Also, according to the invention, the detector cannot rectify the transmission wave when the antenna is not connected to the transmitter unit since the illustrated antenna unit has a demodulation circuit. Therefore, it is easy to determine whether the antenna unit is normally connected or not.

[0071] Further, according to the invention, it is previously possible to know an impedance between the transmitter unit and the antenna unit since the detector is included in the antenna unit. Further, the antenna unit is correctly matched with the transmitter unit in impedance since the above-mentioned impedance can be fed back to the matching circuit.

What is claimed is:

1. A radio apparatus including an antenna unit which radiates a transmission signal and a transmitter unit which supplies the transmission signal to the antenna unit through a line between the transmitter unit and the antenna unit,

the antenna unit comprising:

a coupler which partially extracts the transmission signal to produce an extracted signal; and

a rectifying circuit which rectifies the extracted signal into a d.c. component signal and superposes the d.c. component signal on the transmission signal;

the transmission unit comprising:

a separating circuit which separates the d.c. component signal from the transmission signal.

2. A radio apparatus as claimed in claim 1, wherein the rectifying circuit includes a detector which rectifies the extracted signal into the d.c. component signal.

3. A radio apparatus as claimed in claim 1, wherein the rectifying circuit includes a first coil which superposes the d.c. component signal on the transmission signal.

4. A radio apparatus as claimed in claim 1, wherein the separating circuit includes a second coil which separates the d.c. component signal from the transmission signal.

5. A radio apparatus as claimed in claim 1, wherein the transmitter unit includes a control circuit which compares the d.c. component signal separated from the transmission signal with a predetermined reference signal and detects trouble when the d.c. component signal is lower than the predetermined reference signal.

6. A radio apparatus as claimed in claim 5, wherein the control circuit further decreases the power of the transmission signal then the d.c. component signal is lower than the predetermined reference signal.

7. A radio apparatus as claimed in claim 6, wherein the transmitter unit further comprising:

a variable attenuator which varies the power of the transmission signal; and

an arithmetic circuit which controls the variable attenuator based on a voltage level of the d.c. component signal separated from the transmission signal.

8. A radio apparatus as claimed in claim 1, wherein the transmitter unit further comprising:

a matching circuit which matches an impedance of the transmitter unit to that of the antenna unit; and

a matching control circuit which controls the matching circuit based on a voltage level of the d.c. component signal separated from the transmission signal.

9. A radio apparatus as claimed in claim 1, wherein the transmitter unit includes a control circuit which determines whether or not the d.c. component signal which is separated from the transmission signal falls within a predetermined range and detects trouble when the d.c. component signal does not fall within the predetermined range.

10. A method of controlling a radio apparatus including an antenna unit which radiates a transmission signal and a transmitter unit which supplies the transmission signal, the antenna unit and the transmitter unit being connected electrically from each other, the method comprising the steps of:

partially extracting, at the antenna unit, the transmission signal;

rectifying, at the antenna unit, the extracted signal into a d.c. component signal;

superposing, at the antenna unit, the d.c. component signal on the transmission signal; and

separating, at the transmitter unit, the d.c. component signal from the transmission signal.

11. A method of controlling an antenna unit remote from a transmitter unit, the antenna unit which radiates the transmission signal and the transmitter unit which supplies the transmission signal being included in a radio apparatus and connected electrically from each other, the method comprising the steps of:

partially extracting the transmission signal;

rectifying the extracted signal into a d.c. component signal; and

superposing the d.c. component signal on the transmission signal.

12. A method of controlling a transmitter unit, the transmitter it which supplies a transmission signal and an antenna unit which radiates the transmission signal being included in a radio apparatus and connected electrically from each other, the method comprising the step of:

receiving a d.c. component signal via the transmission signal from the antenna unit; and

separating the d.c. component signal from the transmission signal.

13. A method as claimed in claim 12 further comprising the steps of:

comparing the d.c. component signal which is separated from the transmission signal with a predetermined reference signal; and

detecting trouble when the d.c. component signal is lower than the predetermined reference signal.

14. A method as claimed in claim 13 further comprising the step of:

decreasing the power of the transmission signal when the d.c. component signal is lower than the predetermined reference signal.

15. A method as claimed in claim 14 further comprising the steps of:

varying the power of the transmission signal based on a voltage level of the d.c. component signal separated from the transmission signal; and

controlling intensity of the transmission signal which is radiated from the antenna unit so that the intensity may be equal to a predetermined value.

16. A method as claimed in claim 12 further comprising the step of:

controlling matching of an impedance of the transmitter unit to that of the antenna unit so that a voltage level of the d.c. component signal separated from the transmission signal may become maximum.

17. A method as claimed in claim 12 further comprising the step of:

determining whether or not the d.c. component signal which is separated from the transmission signal falls within a predetermined range; and

detecting trouble when the d.c. component signal does not fall within the predetermined range.

* * * * *